House-Price Crash and Macroeconomic Crisis: A Hong Kong Case Study

Tongbin Zhang and Bo Hu

School of Economics, Shanghai University of Finance and Economics

22. November 2011

House Prices Crash and Macroeconomic Crisis: A Hong Kong Case Study

Bo Hu and Hewitt Zhang

School of Economics, Shanghai University of Finance and Economics

Abstract

House prices crash has become an important feature of macroeconomic crisis. We argue that house prices crash driven by contractionary monetary policy is not only a reaction to crisis, but also accelerates and amplifies the fluctuations of major macroeconomic variable. In this paper, we conduct a case study of Hong Kong in the 1997–1998 financial crisis and quantitatively analyze the mechanism by developing a general equilibrium model incorporating financial accelerator mechanism into both household and entrepreneur sectors. After estimating and simulating the model, impulse response results imply that our model can explain the co-movement of house prices, consumption, and investment better than the alternative models.

I. Introduction

House prices fluctuations have become one increasingly prominent characteristic of economic crisis. The recent financial crisis in the United States was caused by the collapse of the housing market, which propelled the U.S. economy into the Great Recession. In fact, researchers have already noted that conditions in the real estate market played a major role in the rapid meltdown in the Southeast Asian financial crisis beginning in 1997 (John Quigley, 2001). A notable fact in Hong Kong during this crisis is a slump in consumption and investment in tandem with a sharp decline in house prices (Figures 1 and 2). However, quantitative studies based on a general equilibrium framework on this issue are still rare. This paper aims to delve into this area by establishing and estimating a general equilibrium model incorporating financial accelerator to understand the interactions between real estate market fluctuations and the aggregate economic dynamics during the Hong Kong financial crisis. Throughout this paper, we will focus on the following two questions: (1) What kind of mechanism causes house prices crash? (2) How do house prices influence the macroeconomic variables, including output, consumption, and investment?

We find two empirical evidences that are closely related to our questions. The first concerns the source of the continuing decline in house prices during a recession. Getler et al. (2004) argued that the increase in the world interest rate forced the central bank to raise the domestic interest rate to maintain the fixed exchange rate regime. Therefore, the unexpected uplift of the world interest rate is the root that provoked the Southeast Asian financial crisis. There is no fundamental or institutional problem in Hong Kong, hence we argue that the shock that dampened the Hong Kong housing market in the Southeast Asian financial crisis might also come from monetary policy. To verify the above idea, a bivariate Bayesian vector autoregression (BVAR) model with Minnesota prior is used to estimate the impulse responses of both private house price index and private office price index following a shock to interest rate based on a sample period from 1995 to 1999 (Figures 3 and 4). A positive shock to interest rate leads to persistent decrease in house price indices, which is in line with the findings of Getler et al. (2004). Therefore, it is reasonable that we use the monetary policy shock as the main shock in our analysis.

The second evidence is related to the question about how house prices impact macroeconomic variables. We argue that their interactions exist not only in Southeast Asian financial crisis, but also for the entire sample period from the 1980s to 2010. Figures 5 to 7 display the estimated impulse responses of output, consumption, and investment following a shock to house prices. These impulse responses are also estimated from a BVAR model. A positive shock to house prices stimulates a persistent increase in macroeconomic variables, among which the response of investment is the most significant, followed by consumption and output.

To understand these salient features of the data, we propose a general equilibrium model based on the financial accelerator model of Bernanke et al. (1999) (BGG hereafter), which describes how the credit market channel may form part of the monetary transmission mechanism. The model focuses on the macroeconomic effects of imperfections in credit markets. Such imperfections generate premia on the external cost of raising funds, which in turn affect borrowing decisions. We introduce two distinctive features into the Dynamic New Keynesian sticky price model with financial acceleration mechanism. The first feature is that we assume that credit constraints exist among households and entrepreneurs. Thus, both face the optimal financial contracts and use real estate as collateral to reduce the agency costs associated with borrowing to finance housing consumption and investment. The approach is to apply financial accelerator in BGG model to both the household and entrepreneur sectors. Thus, the BGG framework links the cost of firms and households external finance to the quality of their balance sheet. When there is an exogenous interest rate shock, this unanticipated rise depresses the demand for houses, which in turn decreases the investment and house prices. The unanticipated decline in house prices decreases the net worth on the part of both homeowners and entrepreneurs, stimulating the external finance premium, which in turn further depresses investment. Then, a kind of multiplier effect arises.

Moreover, the crash in house prices could directly influence consumption through transfers and output through the decrease in office input. Thus, a shift in housing demand caused by an interest rate shock can lead to large fluctuations in house prices, and produce a broad impact on consumption, investment, and output.

Another feature of our model, compared with other literature, is the introduction of real estate producers into the model. Being different from the final goods producers, real estate producers manufacture real estate services using investment (final goods) and lands without being constrained on borrowing. This more convincing assumption improves the treatment of house supply in existing literature, which assumes that house supply is fixed.

To evaluate our model quantitatively, we estimate the model using calibration and Bayesian methods with Hong Kong aggregate time-series data. Compared to models that only have financial accelerator in either households or firms, our benchmark model provides a much better explanation of the co-movements of house prices, investment, and consumption, as well as the persistence of fluctuations observed in Hong Kong. Our estimation also indicates that propagated through financial accelerators, an interest rate shock alone accounts for about 95% of house prices fluctuations, and more than 70% of fluctuations in macroeconomic variables, including consumption and investment.

A strand of recent DSGE literature on house prices assumes that either households or entrepreneurs are credit constrained, and they use houses or lands as collateral to finance consumption or investment expenditures (Aoki et al., 2004; Iacoviello, 2005; Iacoviello and Neri, 2010; Liu, Wang and Zha, 2011). Aoki et al. (2004) assume that houses provide housing services to consumers and serve as collateral to lower borrowing cost for homeowners. They show that this financial friction amplifies and propagates the effects of the monetary policy shock on housing investment, house prices, and consumption. Similarly, Iacoviello (2005) and Iacoviello and Neri (2010) analyze the relationship between house prices and consumption based on the idea that consumers are credit constrained, and they use houses as collateral to finance their consumption. On the other hand, Liu, Wang, and Zha (2011) introduce credit constraint into the producer side and explain the positive co-movement between land prices and investment. Although these models are capable of explaining the interaction between house prices and consumption or house prices and investment, they have difficulty in delivering positive co-movements of all the three variables simultaneously.

Also, our model is different from those in other literatures on house prices (Ortalo–Magne et al., 2006; Li et al., 2007; Kiyotaki et al., 2010), which mainly focus on the long-run trend of house prices by employing the life cycle model. In contrast, we aim to explain house prices crash in the short run, especially during a recession. Our model is also distinctive from those in existing literature in terms of the interaction between the housing market and the macro economy (Case and Shiller, 1988; DiPasquale and Wheaton, 1992). Their concern is the response of the housing market to aggregate fluctuations. Instead, we are interested in explaining the fact that the housing market could exert great impact on macroeconomic variables rather than the other way round.

The rest of the paper is organized as follows. Section 2 presents our benchmark model based on Dynamic New Keyesian sticky price model. Section 3 estimates structural parameters of the model. Section 4 presents the simulation results, drawing comparisons between alternative models and evaluate the relative importance of shocks. Conclusions are contained in Section 5.

II. The Benchmark Model

In this section we build a New Keynesian sticky price model incorporating financial accelerator mechanism in order to explain the features of the data. The mechanism is anticipated to be developed that a positive shock from monetary policy will generate house prices crash, which amplifies and propagates major macroeconomic variables fluctuations. Also, fluctuations in macroeconomic variables will further exacerbate house prices decline. The economy consists of five types of representative agents: household, entrepreneur, real estate producer, retailer, and monetary authority. There are three types of commodities: houses (or offices for the entrepreneur), nondurable goods and labor. Each household is treated as a composite of two behavioral types: homeowner and consumer. Homeowners purchase houses, and then rent them to consumers. Consumers' utility depends on nondurable goods consumption, housing services and leisure. Entrepreneurs demand office and input them as a production factor to produce wholesales goods. Real estate producers supply houses and offices. Retailers differentiate wholesales goods to gain pricing power. Finally, the monetary authority supports some kind of interest rate rule. Most importantly, borrowing constraints exist in both household and entrepreneur sectors. As their activities are somewhat conventional, we start with households' decision problem.

A. The representative household

The major difference between our model and basic New Keynesian model in household sector lies on the borrowing constraint in purchasing housing services. To avoid the complexity inherent in modeling the dynamic optimization problem of heterogeneous consumers under different borrowing constraints, we follow the method of Aoki et al.(2004). That is, each household is a combination of two behavioral agents: homeowner and consumer. According to Aoki et al.(2004), this separation has the advantage of making the analysis simple, but without losing the essence of the financial accelerator mechanism.

In case of being confused, we first introduce some useful notations in the model.

1. The CES aggregator of consumption.—Consumers demand nondurable consumption goods c_t and house services h_t. C_t denotes a CES consumption aggregator of the form

$$C_t = [\lambda^{1/\eta} c_t^{(\eta-1)/\eta} + (1-\lambda)^{1/\eta} h_t^{(\eta-1)/\eta}]^{\eta/(\eta-1)} \tag{1}$$

Here nondurable consumption goods c_t is a Dixit-Stiglitz aggregator of differentiated consumption goods $c_t(i)$, indexed by $i \in (0,1)$ as

(2) $$c_t = [\int_0^1 c_t(i)^{(\varepsilon-1)/\varepsilon} di]^{\varepsilon/(\varepsilon-1)}$$

Hence the corresponding price index for nondurable consumption goods is given by

(3) $$P_{c,t} = [\int_0^1 p_t(i)^{1-\varepsilon} di]^{1/(1-\varepsilon)}$$

Let P_t denotes the composite price index of C_t, which is defined as

(4) $$P_t = [\lambda P_{c,t}^{1-\eta} + (1-\lambda) P_{h,t}^{1-\eta}]^{1/(1-\eta)}$$

2. Homeowner's economic behavior.—The house purchase decisions of the household sector are made by homeowners. At the end of each period, homeowners purchase houses at price Q_t from real estate producers, and then rent them to their consumers at a rental price $P_{h,t+1}$ in the subsequent period. Homeowners finance the purchase of houses partly with their own net worth available at the end of period t, N_{t+1}^H and partly by borrowing, b_{t+1}. That is,

(5) $$\begin{aligned} q_t h_{t+1} &= N_{t+1}^H + b_{t+1} \\ q_t &= Q_t / P_t \end{aligned}$$

Homeowners' demand for houses depends on expected marginal return on housing and expected marginal financial costs. The expected marginal return $R_{h,t+1}$ is given by

(6) $$E_t[R_{h,t+1}] = E_t[\frac{X_{h,,t+1} + (1-\delta) q_{t+1}}{q_t}]$$

where $0 < \delta < 1$ is the depreciate rate of houses, and $X_{h,t+1}$ is the rental price relative to the composite price index.

Then we switch to the expected marginal financial costs. The first assumption here is that homeowners are risk neutral. In the environment with asymmetric information, homeowners face an external finance premium caused by financial market imperfection when borrowing. For individual homeowners, the return to houses is sensitive to idiosyncratic risk. When borrowers announce that they cannot repay the debt, the lenders cannot observe the realized return unless they pay a fixed "auditing cost". Hence the uncollateralized external financial cost may be more expensive than internal finance due to this "costly state verification" problem. Thus the optimal contract will be a debt contract. That is when the borrower announces he is unable to repay, the lender takes possession of all the borrower's assets. Following BGG's derivation, the external finance premium can be expressed as a decreasing function of the net worth to asset ratio, $N_{t+1}^H/q_t h_{t+1}$, according to the optimal contract. The optimality condition for homeowners' demand for houses is given by

$$
\begin{aligned}
E_t[R_{h,t+1}] &= f(N_{t+1}^H/q_t h_{t+1})R_{t+1} \\
f' &< 0
\end{aligned} \tag{7}
$$

where R_{t+1} is the riskless real interest rate. The assumption of risk neutrality guarantees that (7) holds for the aggregate level.

Since external financial premium depends on homeowners' financial condition, the evolution of net worth is the key to determine homeowners' demand on houses. Let V_t^H denote the value of homeowners at the beginning of period t, given by

$$V_t^H = R_{h,t}q_{t-1}h_t - f(N_t^H/q_{t-1}h_t)R_t(q_{t-1}h_t - N_t^H) \tag{8}$$

Then homeowners' net worth can be defined as

$$N_{t+1} = V_t - D_t \tag{9}$$

where D_t is homeowners' transfer to consumers. The transfer D_t in our model represents the distribution of housing equity between homeowners and consumers. This setting is to capture the important economic behavior in the reality that households use their housing equity to finance consumption. Thus the link between house prices and consumption has been established. Households face the trade-off between current consumption and future finance premium. The rise of house prices can increase the transfer and hence consumption and utility today. However, this also implies a decrease in homeowners' net worth, and an increase in the future finance premium. The optimal allocation should depend on some factors such as the elasticity of intertemporal substitution and future income uncertainty. Following Aoki et al.(2004), to make it simple, we set the transfer to be an increasing function in the net worth of household relative to their assets. That is,

$$
\begin{aligned}
D_t &= \chi(N^H_{t+1}/q_t h_{t+1}) \\
\chi' &> 0
\end{aligned}
\tag{10}
$$

3. Consumer's economic behavior.—There are two types of consumers in our economy: normal consumers and Rule-of-Thumb(ROT) consumers. Normal consumers have accumulated enough wealth, thus they make standard intertemporal and intratemporal decisions. ROT consumers don't have sufficient wealth to smooth consumption. Their marginal propensity to consume is higher than that of the former due to borrowing constraints or impatience. In general, ROT consumers can represent young people in the society.

3.1. The representative normal consumers' utility maximization problem is

$$
\max E_t \sum_{k=0}^{\infty} \beta^k [\log C^p_{t+k} - \xi \frac{(M^p)^{1+\varphi}_{t+k}}{1+\varphi}] \tag{11}
$$

$$
s.t.\ P_t C^p_t + B_{t+1} = W_t C^p_t + R^n_t B_t + \Pi_t
$$

where superscript p denotes normal consumers, C_t^p is the consumption of composite goods, M_t^P is labor supply, R_t^n is the riskless nominal interest rate, W_t is the nominal wage.

3.2. The income of ROT consumers come from wage income and the transfer paid out by homeowners. And they will consume all their current income and save none at the end of each period (Campell and Mankiw, 1989). In order to guarantee enough income, ROT consumers supply labor inelastically. The consumption of the ROT consumers is given by

$$C_t^r = w_t + D_t \tag{12}$$

where superscript r denotes ROT consumers, w_t is the real wage.

3.3 The fraction of normal consumers in the economy is $0 < n_p < 1$. Thus, aggregate consumption is then

$$C_t = n_p C_t^p + (1 - n_p) C_t^r \tag{13}$$

Correspondingly, the aggregate labor supply is

$$M_t = n_p M_t^p + (1 - n_p) \tag{14}$$

B. The representative entrepreneur

Entrepreneurs combine offices with labor to produce wholesale products according to a constant return to scale production function. We describe entrepreneurs' production process with a Cobb-Douglas production function, given by

$$Y_t = F(M_t, O_t) = A_t M_t^{1-\alpha} O_t^{\alpha} \tag{15}$$

where A_t is an exogenous technology, O_t is the aggregate amount of offices purchased by entrepreneurs in period $t-1$, M_t is the labor input.

Similarly, entrepreneurs have the borrowing constraint problem as homeowners in purchasing houses. Entrepreneurs purchase offices at price Q_t in each period for the use in the subsequent period. However, entrepreneurs can't finance the purchase of offices solely with their own net worth. For individual entrepreneurs, the return to offices is sensitive to idiosyncratic risk, which is not observable for lenders. Therefore, entrepreneurs face the external finance premium when borrowing. And the optimal borrowing contract guarantees riskless real interest rate for lenders' expected return. The demand for offices depends on expected return and expected marginal financial costs. The expected return of office $R_{o,t+1}$ is defined as

$$E_t[R_{o,t+1}] = E_t[\frac{\frac{X_{c,t+1}}{X_{t+1}}\frac{\alpha Y_{t+1}}{O_{t+1}} + (1-\delta)q_{t+1}}{q_t}] \tag{16}$$

where $X_{c,t}$ is the price of nondurable goods relative to composite goods, X_t is the gross markup of retail goods over wholesale goods, δ is the depreciate rate.

Following BGG, external finance premium is the decreasing function of the ratio of net worth to assets value in the optimal contract. Be analogous to homeowners, the optimal demand for office is given by

$$\begin{aligned} E_t[R_{o,t+1}] &= \Phi(N^E_{t+1}/q_t O_{t+1})R_{t+1} \\ \Phi' &< 0 \end{aligned} \tag{17}$$

The dynamic behavior of office demand depends on the evolution of entrepreneurs' net worth, N_{t+1}. The more net worth entrepreneurs have, the more mortgage they can get. Thus in the equilibrium entrepreneurs can postpone their consumption to accumulate enough net worth until they don't need to borrow. In order to prevent this, entrepreneurs are assumed to have a probability ν to survive into next period at the end of each period. Entrepreneurs' net worth is defined as

$$N_{t+1}^E = \nu V_t^E + W_t^E \tag{18}$$

$$V_t^E = R_{o,t} q_{t-1} o_t - \Phi(N_t^E / q_{t-1} o_t) R_t (q_{t-1} o_t - N_t^E) \tag{19}$$

where N_t^E is entrepreneurs' net worth, V_t^E is entrepreneurs' equity. Then entrepreneurs who fail in period t consume the residual equity which is

$$C_t^E = (1-\nu) V_t^E \tag{20}$$

C. The representative real estate producer

One feature of our model is the elastic housing supply, which distinguishes our model from other literatures that assumes fixed housing supply (Iacoviello 2005, Liu, Wang and Zha 2011). Real estate producers input land and final goods to produce housing services. Then real estate producers sell housing services to homeowners and entrepreneurs at a nominal price Q_t. The production function of houses is given by

$$Z_t = L^{1-\gamma} I_{z,t}^{\gamma} \tag{21}$$

where Z_t is the flow of houses, L is the land input, $I_{z,t}$ is the final goods input. Following the method of Kiyotaki et al. (2011), the supply of land is fixed. This assumption generates the following mechanism: the more fraction the land value takes in housing value, the more violently house prices response to the exogenous shock. Peng and Wheaton (1994) provided empirical evidences supporting this in Hong Kong by econometric tests under the restriction of land supply set by Hong Kong government. According to the principle of profit maximization, the house price Q_t is given by

$$Q_t = \frac{1}{\gamma} P_{c,t} L^{\gamma-1} I_{z,t}^{1-\gamma} \tag{22}$$

The stock of houses T_t is

$$T_t = (1-\delta)T_{t-1} + Z_t \tag{23}$$

T_t can be used as houses or offices interchangeably. The real estate market clear condition is

$$T_t = h_t + O_t \tag{24}$$

D. Retailer

As is standard in literatures, to motivate sticky prices we modify the model to allow for monopolistic competition retailers. Retailers buy wholesale goods from entrepreneurs, and then differentiate them. Retailers have the power of pricing and sell their products $Y_t(i)$ at the price $P_{c,t}(i)$. In each period, only a fraction $1-\theta$ of retailers are allowed to change their prices (Calvo,1983). Hence, retailer i choose the optimal price $P_{c,t}^*$ to maximize the expected discounted profits

$$\max \sum_{k=0}^{\infty} \theta^k E_{t-1} [\Lambda_{t,k} \frac{P_{c,t}^* - P_t^w}{P_t} Y_{t+k}^*(i)] \tag{25}$$

where $\Lambda_{t,k} = \beta \frac{c_t}{c_{t+k}}$ is the household intertemporal marginal rate of substitution, $P_t^w = \frac{P_{c,t}}{X_t}$ is the nominal price of wholesale goods. The aggregate price evolves according to

$$P_{c,t} = [\theta P_{c,t-1}^{1-\varepsilon} + (1-\theta)(P_{c,t})^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \tag{26}$$

In the economy, final goods can be defined as a CES aggregator of retail goods.

$$Y_t^f = [\int_0^1 Y_t(i)^{(\varepsilon-1)/\varepsilon} di]^{\varepsilon/(\varepsilon-1)} \tag{27}$$

Final goods can be used as nondurable goods consumption, entrepreneurs' consumption, investment and government expenditure. The economy resource constraint is

$$Y_t^f = c_t + C_t^e + I_{z,t} + G_t \tag{28}$$

E. Monetary Authority

Since our mode aims to quantify the responses of house prices and macroeconomic variables to the monetary policy shock, the existence of monetary authority is necessary. The monetary authority in our model is assumed to support a Taylor rule. Monetary authority adjusts the interest rate to meet two aims: targeted inflation rate and smoothed interest rate. When there is an exogenous interest rate shock, the unanticipated rise in nominal interest rate depresses the demand of houses, which in turn decreases the investment and house prices. The unanticipated decline in the asset prices decreases net worth in both homeowners and entrepreneurs part, stimulating the external finance premium, which in turn further depresses investment. Then a kind of multiplier effect arises. The crash in house prices directly influence consumption through transfers D_t and output through the decrease in office input O_t.

Until now, the complete DSGE model has been established. We will log-linearize the first order conditions and market clear conditions to study the responses of economic system to exogenous shocks.

III. Calibration and Bayesian Estimation

The time unit in the model is meant to be a quarter. We assign values to the structural parameters using a combination of calibration and econometric estimation techniques.

We calibrate most parameters using long-run data relations from Hong Kong as well as parameter values that are common in related studies. We set the quarterly discount factor β to 0.99, which also pins down the steady state quarterly riskless rate $R = \beta^{-1}$. The values assigned to $C/Y, I^z/Y, G/Y$ are $0.6, 0.25$ and 0.2 respectively, which are in accord with the history average of Hong Kong. The share of consumption accruing to entrepreneurs' labor accordingly equals to 0.05. The value assumed for λ implies that housing rent expenditure accounts for 12% of total consumption at the steady state. According to statistics from Hong Kong Rating and Valuation Department, the annual rate of return for private houses and private offices are 4.8% and 8.4% respectively. We therefore set $R^h = 1.012$ and $R^o = 1.021$. As is also within convention, the capital share α is 0.35. We assume firms' quarterly survival rate is 0.973 according the bankruptcy and merge data of listed companies in Hong Kong. We set the probability a firm does not change its price within a given period, θ, equal to 0.75, implying that the average time between price adjustment is four quarters. In the monetary policy rule, we set the autoregressive parameter, ρ, to 0.95 and the coefficient ζ on inflation equal to 2, which are standard and make the interest rate smooth.

The parameters governing the financial accelerator are similar to those used in BGG. We define households' leverage ratio ϕ^h as one minus debt to disposable income ratio. We calibrate it as $1/1.4$, which is in line with the average value observed in Hong Kong. Firms' leverage ratio is set as 0.5, the same as BGG. The elasticity of the external finance premium with respect to leverage is an important parameter in our model as it determines the borrowing ability for firms and households. Since there is no way to identify it in the factual data, we set this elasticity for households equal to 0.1 following Aoki et al. (2004), and set it as 0.05 for firms according to BGG. The appendix table presents the calibrated parameter values.

We estimate the remaining parameters of the model using Bayesian methods and Hong Kong data on output, private consumption and house price index over the period 1980Q1 to 2010Q4. Specifically, we estimate seven structural parameters, namely, the five ratios or elasticity parameters that can not be calibrated accurately, $O/T, \omega = w/c^r, n_p, s, \gamma$, and parameters defining the stochastic process of shocks, ρ_g and ρ_a. As Liu et al. (2011), we impose Beta prior distributions on all structure parameters except s. The mean of these prior distributions are set as the calibrated values in Aoki et al. (2004). Aoki et al. (2004) argued that the elasticity of transfer with respect to housing equity changed from 3 to 30 based on UK history; therefore, we assume that the prior for adjustment factor s in the dividend rule follows a uniform distribution over $[3, 30]$. We also estimate three nonstructural parameters, $\sigma_{er}, \sigma_{eg}, \sigma_{ea}$, representing the standard deviations of i.i.d. errors with inverse gamma prior distributions. The prior distributions are summarized in Table 1.

Table 1 also reports the estimates of structural and shock parameters at the posterior mode along with standard deviations. The steady ratio O/T is estimated as 0.4275, implying that private offices occupy 42.75% of the total produced houses. The estimated ratio of wage to consumption for ROT consumer, ω, is 83.36%. The ratio of common consumer, n_p, is estimated to 74.02%. These parameters are broadly in line with those reported in literatures (Aoki et al., 2004; Iacoviello, 2005). The estimated parameter γ (0.1060) in housing production function implies that land value accounts for nearly 90% of housing values. Davis and Heathcote's (2007) empirical evidence shows that fluctuations in real estate values are primarily driven by changes in land prices. Liu et al.(2011) also regards land as the main factor in the housing market that their DSGE model focus on land prices and macroeconomic fluctuations. Therefore, we believe the housing production function in our model is reasonable estimated. Finally, the estimation reveals that the two common shocks—government expenditure shock and technology shock— are persistent and have a modest deviation.

IV. Model Results Analysis

A. Effects of amplification and persistence

So how well does the financial accelerator work in our world? In this section, we present some impulse responses of the model to a contractionary monetary policy shock. There are two ways to evaluate the amplification and persistence effects of our benchmark model.

The first one is to compare the impulse responses of our model to actual data. From the results of BVAR model in section 2, the responses of investment to house price shock has the largest magnitude, followed by the responses of consumption, and that of output is the last. Besides that, private house price index and private office price index response negatively to a positive shock in interest rate. Those are the results we want to match in our model.

Figure 8 displays the impulse responses of major macroeconomic variables in our benchmark model. The shadow areas represent the 68% posterior probability bands. In the linear equilibrium system, we introduce a positive interest rate shock and generate the impulse responses of house price, output, consumption and investment. From the perspective of amplification effect, house prices, output and consumption all drop by 20%. And investment drops most, more than 25%. As we switch to persistence effect, consumption takes 10 periods to recover and output takes 15 periods, and house prices and investment need more than 25 periods to return to steady state. These impulse responses match the BVAR evidences well.

The second way to examine the effects of the model is to compare impulse responses generated by the benchmark model to those of alternative models which turn off financial accelerator in either household sector or entrepreneur sector. The parameters in alternative models take the same values of those estimated in benchmark model. Figure 9 highlights the effect on house price, output, consumption and investment when financial accelerator turns off in the household sector. Investment drops almost 25%, which is the same as the benchmark model, whereas the amplification effect on house price, output and consumption is much weaker, which drops by 17%, 17%, and 15% respectively. Surprisingly, the persistence of impulse response that takes all variables 40 periods to recover contradicts with our intuition. In the other alternative model which is showed in figure 10, we correspondingly is turned off financial accelerator in entrepreneur sector. Both the amplification and persistence effects become weaker than our benchmark model. The peak responses of house price, output, consumption and investment to monetary policy shock are 14%, 15%, 17%, and 18%. As is expected, all variables only need 10 periods to return to steady state. Thus, compared with these alternative models, the benchmark model has advantages in both amplification and persistence.

B. What shocks drive the house prices?

Our estimated model helps us assess the relative importance of the shocks in driving fluctuations in house price and macroeconomic variables. We do this through variance decompositions. Table 2 reports the results of house prices and several key macroeconomic variables across the 3 types of structural shocks at forecasting horizons between the impact period (1Q) and six years after the initial shocks (24Q).

A neutral technology shock (i.e., a TFP shock) contributes little to house price fluctuations, though it accounts for a substantial fraction of fluctuations in investment, consumption and output. The reason lies in the fact that it can only move house prices in entrepreneur sector, thus its impact is much less amplified through financial acceleration. This finding is consistent with Liu et al. (2011), who report weak amplification and propagation effects of macroeconomic variables following a TFP shock after incorporating financial frictions into their DSGE model. A shock to government demand explains little of the fluctuations in house prices and key macroeconomic variables. This is intuitive based on the reason that it can only influence variables through the increase in demands for final goods, which is both indirect and weak.

In contrast, the interest rate shock drives more than 97% of house price fluctuations. Working through financial accelerators in both households and firms, the interest rate shock cases a substantial fraction of fluctuations in investment (about 80%), consumption (about 83-90%) and output (about 82-90%). This finding corroborates the results obtained by Jermann and Quadrini (2009) and Aoki et al. (2004), which showed that financial shocks can impact the borrowing ability of firms and households, and thus play important roles in business cycles.

V. Concluding Remarks

In this paper, we study the house prices crash and its influence on major macroeconomic variables through the case of Hong Kong during the Southeast Asian financial crisis. First, we establish the responses of output, consumption, and investment to the house price shock using bivariate Bayesian VAR models and identify the interest rate shock as the one that results in house prices crash. Then in order to implement quantitative studies in a general equilibrium framework, we build a model with financial accelerator mechanism exits both in the household and entrepreneur sectors. The model focuses on the macroeconomic effects of imperfections in credit markets due to asymmetric information. Such imperfections generate external financial premium on households and entrepreneurs when they raise funds to finance their housing purchase. Moreover, the external financial premium is a function of net worth, which heavily depends on house prices. When a positive interest rate shock comes, the decline in house prices raises the external financial premium, which leads to a reduction in housing demand. Thus, the financial accelerator in both sectors amplifies and propagates the fluctuations in house prices and macroeconomic variables.

We use the combination of calibration and Bayesian estimation to assign values to the structural parameters and compare the impulse responses of our benchmark model with those of two alternative models. We conclude that our model can match the data well and exert better effects in both amplification and persistence than models with financial accelerator solely exits in household sector or entrepreneur sector.

In the subsequent research we hope to extend our model to work in a small open economy.

Given the important role of the foreign exchange rate regime in economic activities not only in Hong Kong, but also in Thailand, South Korea, and Indonesia, with sufficient data preparation in these emerging countries, we would like to investigate the influence of foreign exchange rate regime on house prices and other macroeconomic variables.

Table 1 Prior and Posterior Distribution

	Prior			Posterior		
Parameter	Distribution	Mean	S.D.	Mode	S.D.	T stat.
O/T	Beta	0.4	0.1	0.4275	0.1473	2.9028
ω	Beta	0.6	0.1	0.8336	0.0619	13.4607
n_p	Beta	0.5	0.1	0.7402	0.0589	12.5654
s	Uniform	3(min)	30(max)	3.0000	0.0557	53.8546
γ	Beta	0.4	0.1	0.1060	0.0337	3.1513
ρ_g	Beta	0.85	0.1	0.7415	0.0449	16.5037
ρ_a	Beta	0.85	0.1	0.7458	0.0430	17.3546
σ_{er}	Inv. Gamma	0.2	2	0.0236	0.0003	77.2450
σ_{eg}	Inv. Gamma	0.2	2	0.2339	00161	14.5079
σ_{ea}	Inv. Gamma	0.2	2	0.1266	0.0218	5.8028

Table 2 Variance decompositions of aggregate quantities

Horizon	Interest Rate	Government Demand	TFP (Technology)
		House Price	
1Q	96.39	0.33	3.28
4Q	98.18	0.21	1.61
8Q	97.92	0.16	1.93
16Q	97.70	0.11	2.18
24Q	97.68	0.10	2.22
		Investment	
1Q	88.57	0.05	11.38
4Q	79.63	0.11	20.26
8Q	77.57	0.12	22.31
16Q	78.97	0.11	20.92
24Q	80.09	0.10	19.81
		Consumption	
1Q	97.56	0.00	2.44
4Q	88.14	0.03	11.83
8Q	83.86	0.06	16.09
16Q	83.44	0.06	16.51
24Q	83.74	0.06	16.21
		Output	
1Q	94.08	0.97	4.95
4Q	85.58	0.74	13.68
8Q	82.62	0.63	16.75
16Q	83.10	0.56	16.33
24Q	83.82	0.53	15.65

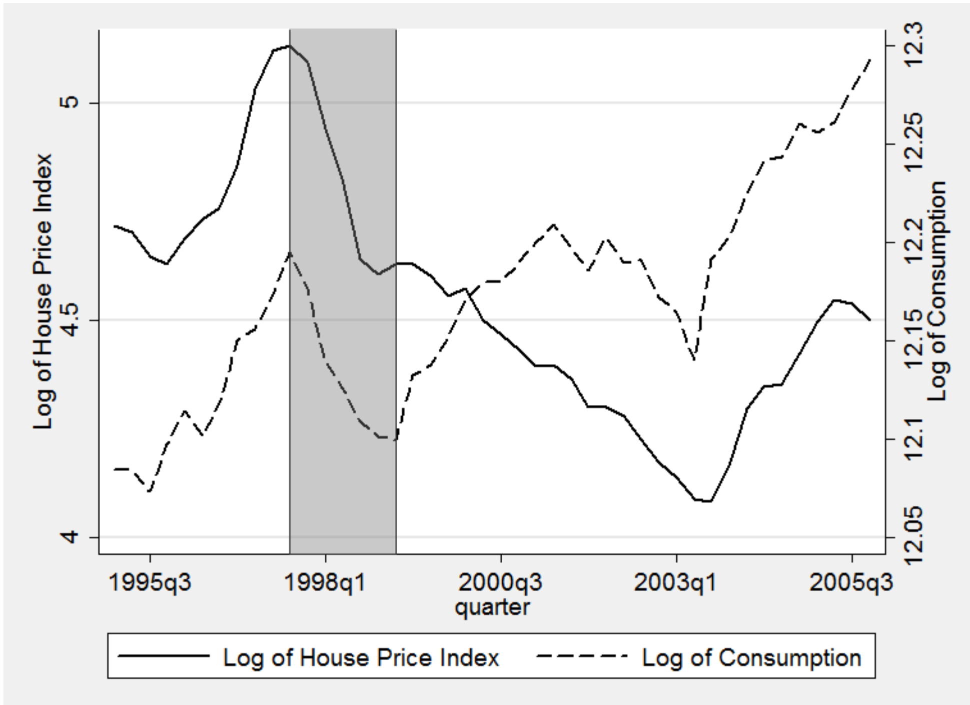

Figure 1: Seasonal adjusted House Prices Index and Consumption from 1995 to 2005, with the financial crisis phase represented by the shaded part (i.e., from 1997 Q3 to 1999 Q4).

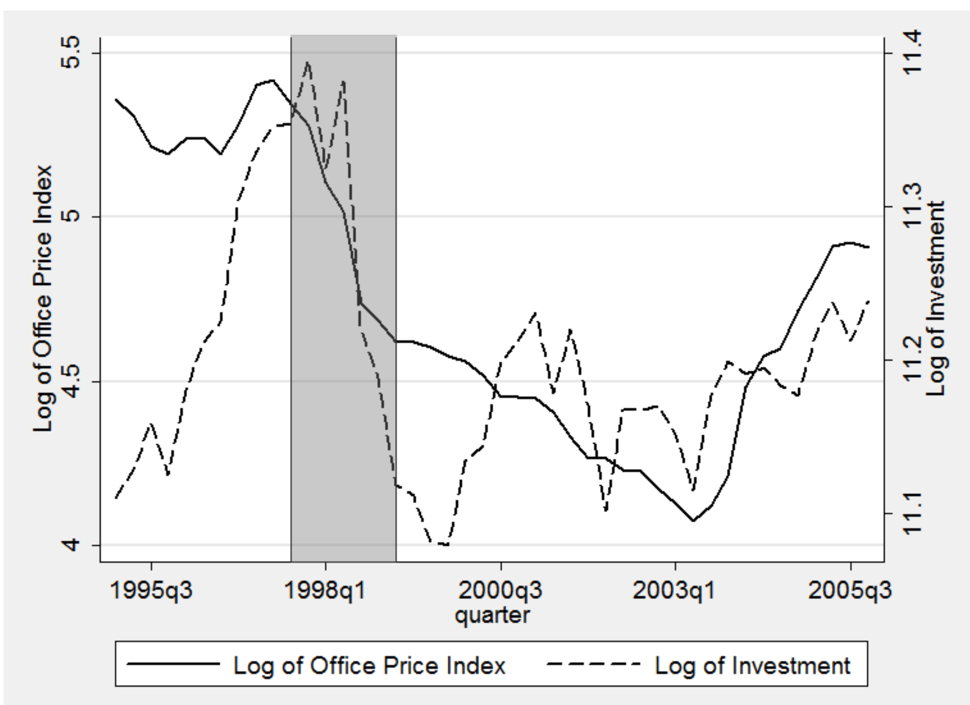

Figure 2: Seasonal adjusted Office Price Index and Investment from 1995 to 2005, with the financial crisis phase represented by the shaded part (i.e., from 1997 Q3 to 1999 Q4).

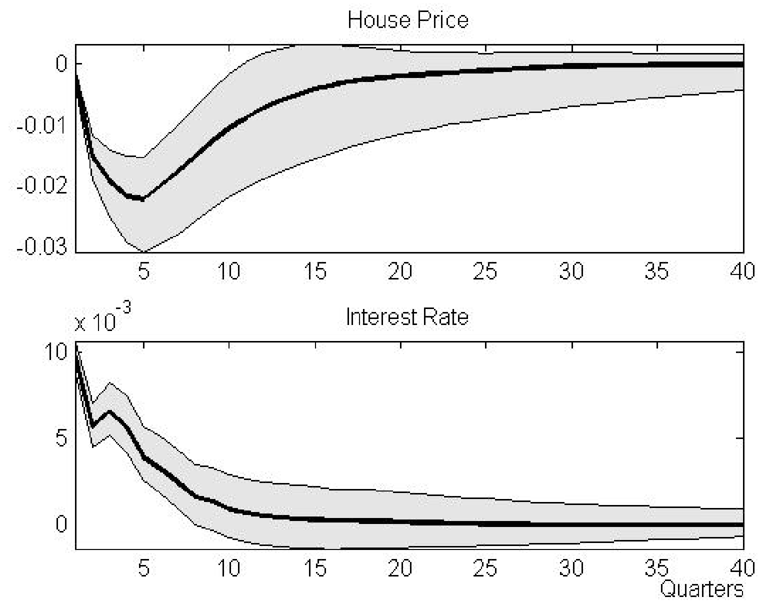

Figure 3: Impluse response to a shock to the interest rate. Note: House price is measured with the private house price index. Interest rate is measured with the six-month foreign exchange funds rate. Solid lines represent the estimated responses from a bivariate BVAR model based on monthly data from January 1995 to December 1999. Darked parts represent the 68% posterior probability bands.

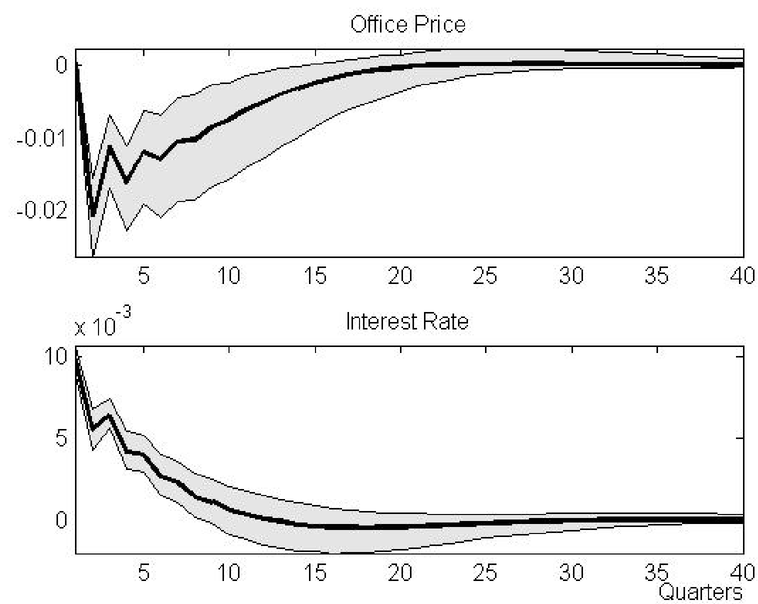

Figure 4: Impulse responses to a shock to the interest rate. Note: Office price is measured with the private office price index. Interest rate is measured with the six-month foreign exchange funds rate. Solid lines represent the estimated responses from a bivariate BVAR model based on monthly data from January 1995 to December 1999. Darked parts represent the 68% posterior probability bands.

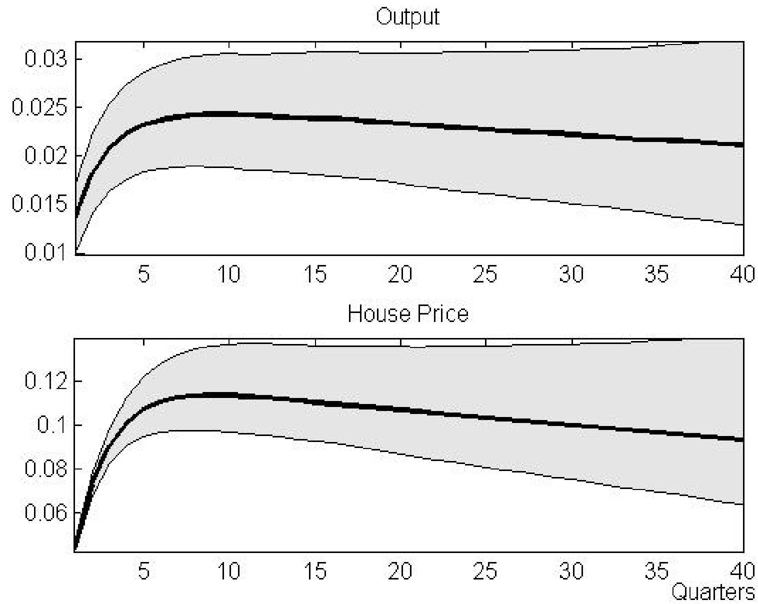

Figure 5: Impulse responses to a shock to the house price index. Note: House price is measured with the private house price index. Solid lines represent the estimated responses from a bivariate BVAR model based on quarterly data from 1980 Q1 to 2010 Q4. Darked parts represent the 68% posterior probability bands.

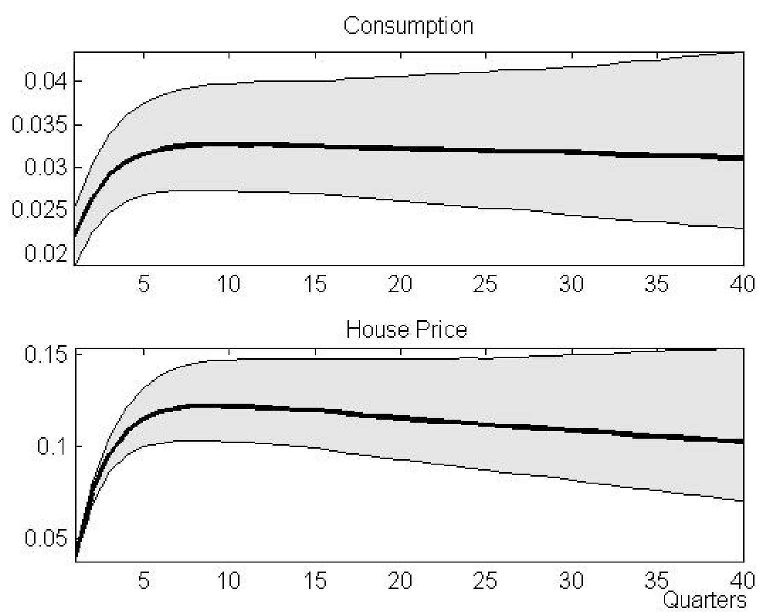

Figure 6: Impulse response to a shock to the house price index. Note: House price is measured with the private house price index. Interest rate is measured with the six-month foreign exchange funds rate. Solid lines represent the estimated responses from a bivariate BVAR model based on quarterly data from 1980 Q1 to 2010 Q4. Darked parts represent the 68% posterior probability bands.

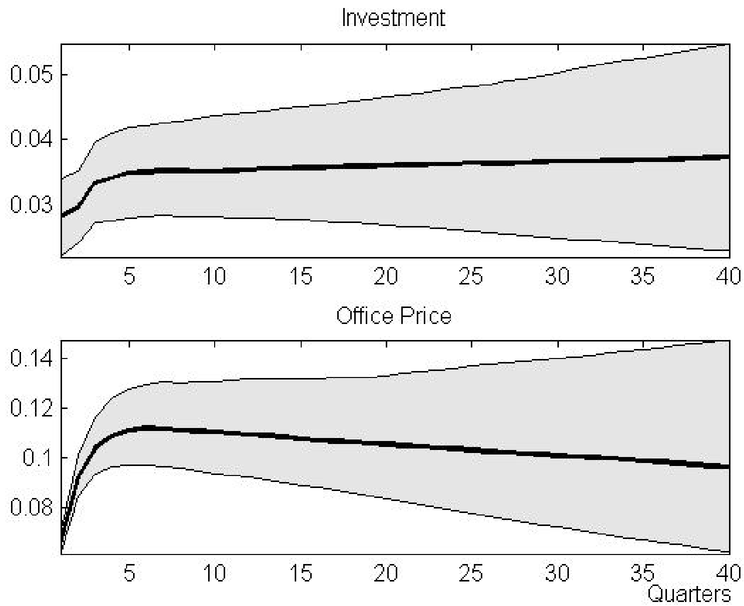

Figure 7: Impulse responses to a shock to office price index. Note: Office price is measured with the private office price index. Interest rate is measured with the six-month foreign exchange funds rate. Solid lines represent the estimated responses from a bivariate BVAR model based on quarterly data from 1986Q1 to 2010Q4. Darked parts represent the 68% posterior probability bands.

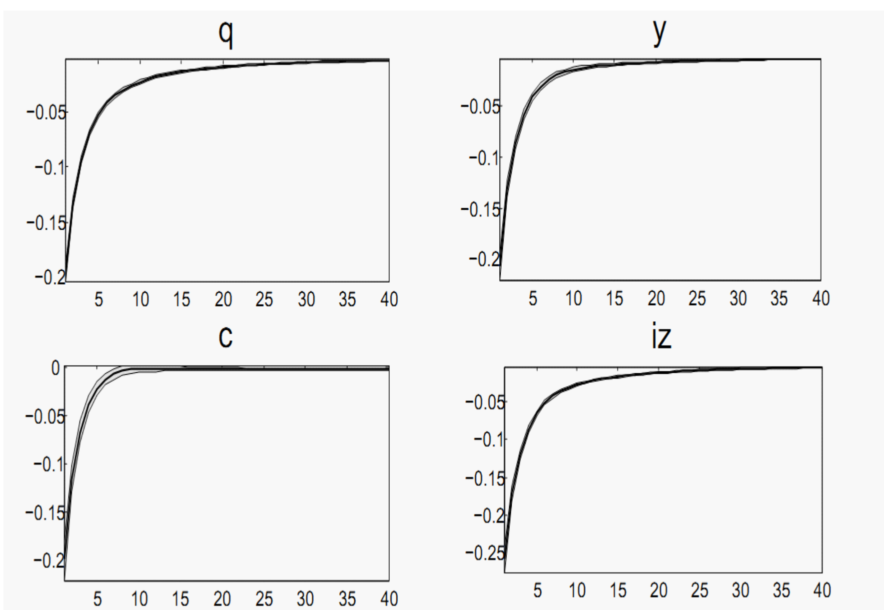

Figure 8: Impulse responses to a shock to the interest rate

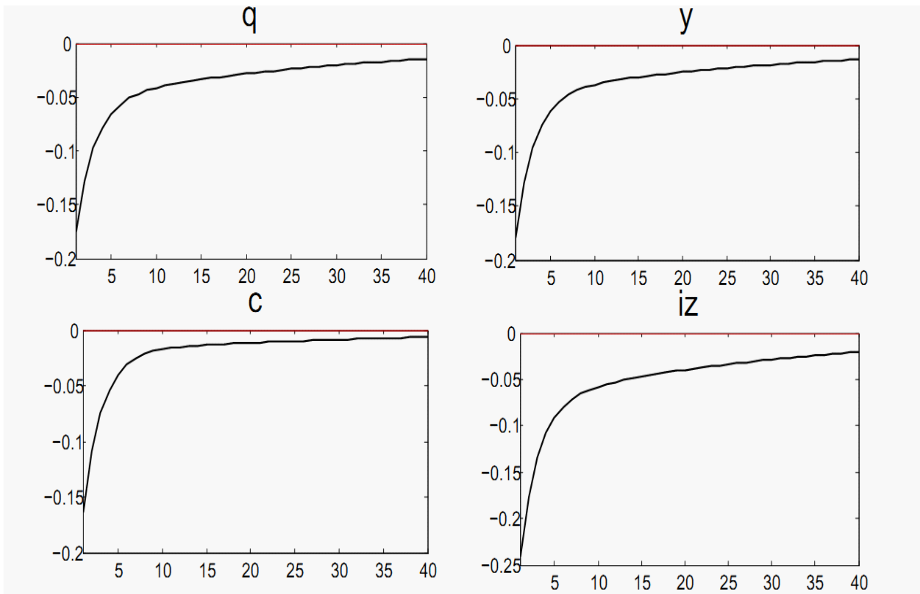

Figure 9: Impulse responses to a shock to the interest rate after turning off the financial accelerator in household sector

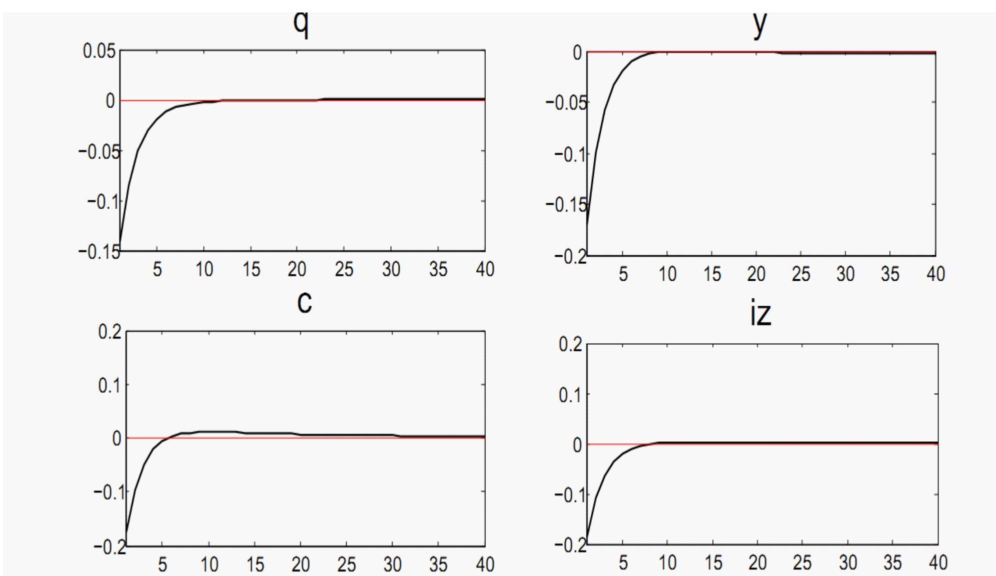

Figure 10: Impulse responses to a shock to the interest rate after turning off the financial accelerator in entrepreneur sector

A Appendix: The Complete Log-Linearized Model

1. Aggregate demand

(A1)
$$y_t = \frac{c}{Y}c_t + \frac{C^e}{Y}c_t^e + \frac{I_z}{Y}i_{z,t} + \frac{G}{Y}g_t$$

(A2)
$$C_t^p = -r_{t+1} + C_{t+1}^p$$

(A3)
$$C_t^r = \omega w_t + (1-\omega)d_t$$

(A4)
$$C_t = n_p C_t^p + (1-n_p)C_t^r$$

(A5)
$$c_t = C_t - \eta x_{c,t}$$

(A6a)
$$h_t = C_t - \eta x_{h,t}$$

(A7)
$$x_t^c = \vartheta x_t^h$$

(A8)
$$r_{t+1}^h = r_t - \nu^h \left(n_{t+1}^h - q_t - h_{t+1}\right)$$

(A9)
$$r_{t+1}^h = (1-\mu^h)x_t^h + \mu^h q_{t+1} - q_t$$

$$d_t = s(n^h_{t+1} - q_t - h_{t+1}) \tag{A10}$$

$$r^h_{t+1} = r_t - \nu^o \left(n^e_{t+1} - q_t - o_{t+1}\right) \tag{A11}$$

$$r^h_{t+1} = (1-\mu^o)(y_{t+1} - o_{t+1} + x^c_{t+1} - x_{t+1}) + \mu^o q_{t+1} - q_t \tag{A12}$$

$$q_t = (1-\gamma) i_{z,t} + x_{c,t} \tag{A13}$$

$$t_t = \frac{O}{T} o_t + \frac{h}{T} h_t \tag{A14}$$

$$c^e_t = (1/\phi^o) r^o_t + (1 - 1/\phi^o)\, r_t + \left(1 + \mu^o \frac{\phi^o - 1}{\phi^o}\right) n^e_{t-1} - \mu^o \frac{\phi^o - 1}{\phi^o} (q_{t-1} + o_t) \tag{A15}$$

2. Aggregate supply

$$y_t = a_t + (1-\alpha) m_t + \alpha o_t \tag{A16}$$

$$w_t = y_t - m_t - x_t + x_{c,t} \tag{A17}$$

$$C^p_t + \varphi m^p_t = w_t \tag{A18}$$

$$m_t = m^p_t \tag{A19}$$

(A20) $$z_t = \gamma i_{z,t}$$

(A21) $$\pi_t = \kappa(-x_t) + \beta\pi_{t+1}$$

3. The evolution of state variables

(A22) $$\begin{aligned} n^e_{t+1} &= \nu * R^o[(1/\phi^o)r^o_t + (1 - 1/\phi^o)r_t + \\ & (1 + \nu^o \frac{\phi^o - 1}{\phi^o})n^e_{t-1} - \nu^o \frac{\phi^o - 1}{\phi^o}(q_{t-1} + o_t)] \end{aligned}$$

(A23) $$t = (1 - \delta)t_{t-1} + \delta z_t$$

4. Monetary policy and shock processes

(A24) $$r^n_t = \rho r^n_{t-1} + (1 - \rho)\zeta\pi_{t-1} + e^{rn}_t$$

(A25) $$g_t = \rho_g g_{t-1} + e^g_t$$

(A26) $$a_t = \rho_a a_{t-1} + e^a_t$$

(A27) $$r^n_t = r_t + \pi_{t+1}$$

(A1) is the goods market clearing. (A2) and (A3) are the consumer's first-order conditions for consumption. (A4) is the aggregate consumption of normal consumers and ROT consumers. The demand for nondurable goods and house services are (A5) and (A6a). (A7) is the price relationship. The external finance premium for homeowners and entrepreneurs are (A8) and (A11). The definitions of return for house and office are respectively (A9) and (A12). (A10) represents the transfer rule. (A13) is the house price definition and (A14) is the house market clearing. The entrepreneur's consumption is (A15).

(A16) is the production function. The combination of (A17), (A18) and (A19) is the labor market clearing conditions. (A20) is the house production function. The New Keynesian Phillips Curve is (A21). (**??**), (**??**) and (A23) are the law of motions for homeowner's net worth, entrepreneur's net worth and house stock. (A24) is Taylor rule. The exogenous process of government expenditure and productivity are (A25) and (A26). (A27) is the definition of real interest rate.

B Appendix: Parameters Calibration

$\frac{c}{Y}$	0.6
$\frac{C^e}{Y}$	0.05
$\frac{I_Z}{Y}$	0.25
$\frac{G}{Y}$	0.1
η	1
$\vartheta = -\frac{1-\lambda}{\lambda}$	-0.14
$\nu^h = \frac{f^{'}(\phi^h)}{f(\phi^h)}\phi^h$	0.1
$\nu^o = \frac{\Phi^{'}(\phi^o)}{\Phi(\phi^o)}\phi^o$	0.05
ϕ^h	1/1.4
ϕ^o	0.5
$\mu^h = \frac{1-\delta}{R^h}$	0.978
$\mu^o = \frac{1-\delta}{R^o}$	0.969
α	0.35
δ	0.01
υ	0.973
θ	0.75
β	0.99
κ	0.0858
ζ	2
φ	1
R^h	1.012
R^o	1.021

REFERENCES

[1] Aoki, Kosuke., James Proudman, and Gertjan Vlieghe. 2004. "House Price, Consumption ,and Monetary Policy: a Financial Accelerator Approach." Journal of Financial Intermediation, 13(4), 414-435.

[2] Bernanke, B., and Mark Gertler. 1989. "Agency Costs, Net Worth, and Business Fluctuations." American Economic Review, 79(1), 14-31.

[3] Bernanke B, and Mark Gertler. 1995. "Inside the Black Box: the Credit Channel of Monetary Transmission." Journal of Economic Perspectives, 9(4), 27—48.

[4] Bernanke, B., M. Gertler, and S. Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework.", The Handbook of Macroeconomics 1C, pp.1341-1393, Amsterdam, North Holland.

[5] Blanchard, Olivier., and Charles M. Kahn. 1980. "The Solution of Linear Difference Models under Rational Expectation." Econometrica, 48(5), 1305-1311.

[6] Calvo, G. 1983. "Staggered Prices in a Utility-maximizing Framework." Journal of Monetary Economics, 12(3), 383-398.

[7] Campbell, J., and Gregory Mankiw. 1989. "Consumption, Income, and interest rates: Reinterpreting the Time Series Evidence." NBER Macroeconomics Annual, 4, 185-216.

[8] Canova, Fabio. 2007. "Method For Applied Macroeconomic Research." Princeton University Press.

[9] Carlstrom, C.T., and T.S. Fuerst. 1997. "Agency Costs, Net worth, and Business Fluctuations: a Computable General Equilibrium Analysis." American Economic Review, 87(5), 893-910.

[10] Case, K.E., and R.J. Shiller. 1998. "The Behavior of Home Buyers in the Boom and Post Boom Market." New England Economic Review, November/December, 29-46.

[11] Cespedes, L., R. Chang, and A. Velasco. 2004. "Balance Sheets and Exchange Rate Policy." American Economic Review, 94(4), 1183-1193.

[12] Chau, K.W., S.K. Wong, C.Y. Yiu, and H.F. Leung. 2005. " Real Estate Price Indices in Hong Kong." Journal of Real Esatate Literature, 13(3), 337-356.

[13] Christiano, Lawrence., Martin Enichenbaum and Charles Evans. 1999. "Monetary Policy Shocks: What We Have Learned and to What End." The Handbook of Macroeconomics 1A, pp.65-148, Amsterdam, North Holland.

[14] Davis, Morris., and Michael Palumbo. 2008. "The Price of Residential Land in Large U.S. Cities." Journal of Urban Economics, 63(1), 352-384.

[15] Dejong, David N., and Chaten Dave. 2007. "Structural Macroeconometrics." Princeton University Press.

[16] DiPasquale, D., and W.C. Wheaton. 1992. "Housing Market Dynamics and the Future of Housing Price." Journal of Urban Economics, 35(1), 1-27.

[17] Gali, Jordi. 2008. "Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework." Princeton University Press.

[18] Gertler, Mark., Simon Gilchrist, and Fabio Natalucci. 2007. "External Constraints on Monetary Policy and the Financial Accelerator." Journal of Money Credit and Banking, 39(2-3), 295-330.

[19] Gottlied, M. 1976. "Long Swings in Urban Development." Columbia University Press.

[20] Iacoviello, Matteo. 2004. "Consumption, House Price, and Collateral Constraints: a Structural Econometric Analysis", Journal of Housing Economics, 13(4), 304-320.

[21] Iacoviello, Matteo. 2005. "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle." American Economic Review, 95(3), 739-764.

[22] Iacoviello, Matteo., and Stefano Neri. 2010. "Housing Market Spillovers: Evidence from an Estimated DSGE Model." American Economic Journal: Macroeconomics, 2(2), 125-64.

[23] Jermann, U., and V. Quadrini. 2009. "Macroeconomic Effects of Financial Shocks." American Economic Review, forthcoming.

[24] Kiyotaki, N. and J. Moore. 1997. ”Credit Cycles.” Journal of Political Economy, 105(2), 211-248.

[25] Kiyotaki, N., A. Michaelides, and K. Nikolov. 2011. “Winners and Losers in Housing Markets.” Journal of Money, Credit and Banking, 43(2), 255-296.

[26] Krugman, Paul. 1999. “The Return of Depression Economics.” W.W Norton Company.

[27] Krugman, Paul. 1998. “What Happened to Asia.” http://web.mit.edu/krugman/.

[28] Li, Wenli., and Rui Yao. 2007. “The Life Cycle Effects of House Price Changes.” Journal of Money Credit and Banking, 39(6), 1375-1409.

[29] Liu, Zheng., Pengfei Wang and Tao Zha. 2011. “Land-Price Dynamics and Macroeconomic Fluctuations.” Federal Reserve Bank of Atlanta Working Paper Series.

[30] Monacelli, Tommaso. 2009. “New Keynesian Models, Durable Goods, and Collateral Constraints.” Journal of Monetary Economics, 56(2), 242-254.

[31] Ortalo-Magne, Francois and Sven Rady. 2006. “House Markets Dynamics: On the Contribution of Income Shocks and Credit Constraints.” Review of Economic Studies, 73(2), 459-485.

[32] Peng, Ruijue., and William Wheaton. 1994. “Effects of Restrictive Land Supply on Housing in Hong Kong: An Econometric Analysis”, Journal of Housing Research, 5(2), 263-292.

[33] Quigley, John. 1999. "Real Estate Price and Economic Cycles." International Real Estate Review, 2(1), 1-21.

[34] Quigley, John. 2001. "Real Estate and the Asian Crisis." Journal of Housing Economics, 10(2), 129-161.

[35] Radelet, Steven. and Jeffery Sachs. 1998. " The East Asian Financial Crisis: Diagnosis, Remedies, Prospect." Brookings Papers on Economic Activity, No.1, 1-90.

[36] Sarno, Lucio., and Mark Taylor. 1999. "Moral Hazard, Asset Price Bubbles, Capital Flows and the East Asian Crisis: the First Test." Journal of International Money and Finance, 18(4), 637-657.

Notes